

TITLE OF THE INVENTION

MOBILE COMMUNICATION SYSTEM

5 CROSS-REFERENCE TO THE RELATED APPLICATION

This application is a continuation of International Application No. PCT/JP99/01295, whose International filing date is March 16, 1999, the disclosures of which Application are incorporated by reference herein.

10

BACKGROUND OF THE INVENTION

1. Field of the Invention

15 The present invention relates to a mobile communication system which permits independent setting of the transmission rates of up- and down-links.

2. Description of the Related Art

20 Mobile communication systems have a structure in which subscriber stations, i.e. mobile stations (such as vehicle-installed communication devices and portable communication devices) are connected to a base station via radio channels.

25 In these mobile communication systems, there is the possibility that sharing of radio frequency spectra (hereinafter referred to as "frequency sharing") by different radio systems is implemented by an FDMA/TDMA combination, while in the CDMA system frequency sharing between different codes or symbols has already been put into practice. Handover in these systems is already known.

For example, time slot sharing mobile communication system which shares a TDMA signal and a time division CDMA signal in the same time slot is disclosed in our U.S. Patent No. 5,805,581 (Japanese Pat. Appln. Laid-Open Gazette No. 8-130766, EP701337A).

5 For instance, in the case of building a multimedia in such a mobile communication system as mentioned above, it is necessary that the channel capacity of an up-link over which the subscriber station sends data to the base station and the channel capacity of a down-link over which the base station sends data to the subscriber station be set independently of each other.
10 Moreover, to cope with variations in the amount of data sent during communication, it is necessary to establish a system which enables the data transmission rate to be changed accordingly.

For example, upon occurrence of a situation in which a momentary increase takes place in the amount of data to be sent from the subscriber station to the base station, the subscriber station computes the transmission rate required taking into consideration the amount of increase in the data to be sent, and sends a request for a change of the transmission rate to the base station.
15

Upon receiving the request for a change of the transmission rate from the subscriber station, the base station determines whether a change of the transmission rate can be accepted after hunting for an idle channel in the link over which they are currently in communication with each other.
20

And, when judging that a change of the transmission rate can be accepted, the base station sends to the subscriber station the identification number of the communication channel to be used thereafter.
25

Upon receiving from the base station the identification number of the communication channel for subsequent use from the base station, the

subscriber station sends data over the designated communication channel to the base station after that.

In this way, the data transmission rate is changed, but since the actual change of the data transmission rate calls for a process of obtaining permission from the distant or remote station, there is a need to allow for a considerable amount of waiting time until the transmission rate is actually changed after the amount of data to be sent changes.

Accordingly, in a mobile communication system in which the amount of data sent undergoes great variations and allowance for an appreciable amount of waiting time is difficult to make, it is customary to adopt a scheme which fixes the transmission rate at a large value by assigning a wide frequency band from the beginning of communication.

Since the conventional mobile communication system has such a configuration as mentioned above, the transmission rate can be changed when permission is obtained from the distant station after sending thereto a request for a change of the transmission rate, but a considerable amount of time is needed until the transmission rate is actually changed. Hence, when the amount of data to be sent varies greatly, congestion of data or the like occurs, leading to, for example, impairment of the immediacy of data sent in real time.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a mobile communication system which enables the data transmission rate to be changed quickly during communication.

According to an aspect of the present invention, time slot changing means of the subscriber station changes the time slot in which to receive data

from the base station in accordance with time slot change information sent from change request means of the base station.

5 This enables the base station to use the new time slot for sending the next and subsequent frames, making it possible to ensure the immediacy of data sent in real time even when the amount of data to be sent varies greatly.

According to another aspect of the present invention, when the change request means of the base station sends time slot change information to the subscriber station, the base station uses the new time slot to send data contained in the next and subsequent frames.

10 This ensures the immediacy of data sent in real time even when the amount of data to be sent varies greatly.

According to another aspect of the present invention, the transmission rate is determined in accordance with an instantaneous amount of data to be sent to the subscriber station.

15 This permits determination of an appropriate transmission rate according to the amount of data to be sent.

According to another aspect of the present invention, an instantaneous amount of data to be sent is detected from that amount of data received from a switching center which has yet to be sent to the subscriber station.

20 This allows ease in detecting the instantaneous amount of data to be sent without using any complicated arrangement.

According to another aspect of the present invention, information for a change of the time slot to be used for sending the next frame is read out of a provisional channel memory provisionally pre-assigned the time slot , and the
25 read-out information is sent to the subscriber station.

This permits quick switching of the time slot.

According to another aspect of the present invention, reservation

information indicating the timing for changing the time slot is sent to the subscriber station together with the time slot change information.

5 This makes it possible for the subscriber station to prepare a time slot changing process in anticipation of a variation in the amount of data to be sent and hence perform the time slot changing process in good time, enabling congestion or the like in the frequency band concerned to be judged.

According to another aspect of the present invention, the subscriber station determines the time slot change timing in accordance with the reservation information sent from the base station.

10 This enables the subscriber station to prepare the time slot changing process in anticipation of a variation in the amount of data to be sent.

According to another aspect of the present invention, when a desired time slot becomes unusable before time slot changing means of the subscriber station changes the current to the new time slot after having received the time slot change information and the reservation information from the base station, the change request means of the base station sends to the subscriber station time slot change information indicating another time slot.

This makes it possible to secure the required transmission rate even if the initially-designated time slot becomes unusable.

20 According to another aspect of the present invention, when receiving the time slot change information indicating another time slot from change request means of the base station, the time slot changing means of the subscriber station changes the time slot for receiving data from the base station in accordance with the time slot change information.

25 This makes it possible to secure the required transmission rate even if the initially-designated time slot becomes unusable.

According to another aspect of the present invention, in the case of

increasing the data transmission rate, it is determined whether to change the transmission rate by referring to the sendable power of a transmitter in the base station.

This prevents cutting of radio connection by switching of the time slot.

5. According to another aspect of the present invention, in the case of decreasing the data transmission rate, it is determined whether to change the transmission rate by referring to the sensitivity of a receiver in the subscriber station and the sendable power of a transmitter in the base station.

10 This also prevents cutting of radio connection by switching of the time slot.

According to another aspect of the present invention, time slot changing means of the base station changes the time slot in which to receive data from the subscriber station in accordance with time slot change information sent from change request means of the subscriber station.

- 15 This enables the subscriber station to use the new time slot for sending the next and subsequent frames, making it possible to ensure the immediacy of data sent in real time even when the amount of data to be sent varies greatly. According to another aspect of the present invention, when the change request means of the subscriber station sends time slot change information to
20 the base station, the subscriber station uses the new time slot to send data contained in the next and subsequent frames.

This ensures the immediacy of data sent in real time even when the amount of data to be sent varies greatly.

- 25 According to another aspect of the present invention, the transmission rate is determined in accordance with an instantaneous amount of data to be sent to the base station.

This permits determination of an appropriate transmission rate

according to the amount of data to be sent.

According to another aspect of the present invention, an instantaneous amount of data to be sent is detected from that amount of data received from a man-machine interface which has yet to be sent to the base station.

- 5 This allows ease in detecting the instantaneous amount of data to be sent without using any complicated arrangement.

According to another aspect of the present invention, information for a change of the time slot to be used for sending the next frame from the subscriber station is read out of a provisional channel memory provisionally
10 pre-assigned the time slot, and the read-out information is sent to the base station.

This permits quick switching of the time slot.

According to another aspect of the present invention, reservation information indicating the timing for changing the time slot is sent to the base
15 station together with the time slot change information.

This makes it possible for the base station to prepare a time slot changing process in anticipation of a variation in the amount of data to be sent and hence perform the time slot changing process in good time, enabling congestion or the like in the frequency band concerned to be judged.

20 According to another aspect of the present invention, the base station determines the time slot change timing in accordance with the reservation information sent from the subscriber station.

This enables the base station to prepare the time slot changing process in anticipation of a variation in the amount of data to be sent.

25 According to another aspect of the present invention, when a desired time slot becomes unusable before time slot changing means of the base station changes the current to the new time slot after having received the time

slot change information and the reservation information from the subscriber station, the change request means of the subscriber station sends to the base station time slot change information indicating another time slot.

5 This makes it possible to secure the required transmission rate even if the initially-designated time slot becomes unusable.

According to another aspect of the present invention, when receiving the time slot change information indicating another time slot from change request means of the subscriber station, the time slot changing means of the base station changes the time slot for receiving data from the subscriber station in accordance with the time slot change information.

This makes it possible to secure the required transmission rate even if the initially-designated time slot becomes unusable.

According to another aspect of the present invention, in the case of increasing the data transmission rate, it is determined whether to change the transmission rate by referring to the sendable power of a transmitter in the base station.

This prevents cutting of radio connection by switching of the time slot.

According to another aspect of the present invention, in the case of decreasing the data transmission rate, it is determined whether to change the transmission rate by referring to the sensitivity of a receiver in the subscriber station and the sendable power of a transmitter in the base station.

This also prevents cutting of radio connection by switching of the time slot.

25 BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of the present invention will become more apparent from the following description taken in conjunction

with the accompanying drawings, in which:

Fig. 1 is a diagram depicting the general outline of a mobile communication system according to a first embodiment of the present invention;

5 Fig. 2 is an explanatory diagram depicting examples of TDMA and time division CDMA time slots for PCS and cellular system use;

Fig. 3 is an explanatory diagram depicting other examples of TDMA and time division CDMA time slots for PCS and cellular system use;

10 Fig. 4 is an explanatory diagram depicting examples of transmission rates of up- and down-links of a radio communication channel between a subscriber station and a base station;

Fig. 5 is an explanation diagram showing a list of channels provisionally pre-assigned time slots to be used to transmit the next frame in the usable data transmission rates shown in Fig. 4;

15 Fig. 6 is a state transition diagram depicting channel switching;

Fig. 7 is a block diagram illustrating the inside (change request means) of a base station in the mobile communication system according to Embodiment 1 of the present invention;

Fig. 8 is a diagram showing a time slot structure in a frame;

20 Fig. 9 is an explanatory diagram depicting time slots provisionally assigned to respective channels and actual time slots of the respective channels;

Fig. 10 is an explanatory diagram showing the state in which when one of the times slots provisionally assigned to the respective channels is actually used, a new time slot is assigned to that time slot;

Fig. 11 is a diagram showing a time slot structure in a frame;

Fig. 12 is a diagram showing a time slot structure in a frame;

Fig. 13 is a flowchart showing the operation of a mobile communication system according to a sixth embodiment of the present invention;

Fig. 14 is a block diagram illustrating the inside (change request means) of a subscriber station of a mobile communication system according to a seventh embodiment of the present invention;

Fig. 15 is a block diagram depicting time slot changing means of the base station which receives TS change information from the subscriber station and changes the time slot accordingly; and

Fig. 16 is a block diagram depicting the inside of a mobile switching center.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

To describe the present invention in more detail, the best mode for carrying out the invention will be described with reference to the accompanying drawings.

EMBODIMENT 1

Fig. 1 is a diagram illustrating the general outline of a mobile communication system according to a first embodiment (Embodiment 1) of the present invention. Reference numerals 1 to 3 denote base stations, 4 a mobile switching center for controlling the base stations 1 and 3, 5 a mobile switching center for controlling the base station 2, and 6 PSTN (Public Switching Telephone Network) which is a public system to which the mobile switching centers 4 and 5 are wire-connected.

Reference characters MS11 to MS14 denote mobile stations which are radio-connected to any one of the base stations 1 to 3, such as mobile

vehicle-installed communication devices or mobile/portable communication devices, and WS21 to WS23 denote half-fixed or fixed FWA (Fixed Wireless Access) stations which are radio-connected to any one of the base stations 1 to 3.

5 The mobile stations and the FWA stations carry out radio communications with any one of the base stations 1 to 3 over a low-speed TDMA data channel, a medium-/high-speed TDMA data channel, a time division CDMA channel and so forth, but they have a channel for carrying out voice or low-speed data communication other than the above-mentioned
10 channels. The mobile stations and the FWA stations will hereinafter be collectively called subscriber stations.

 While in this embodiment the mobile switching centers 4 and 5 are wire-connected to the PSTN 6, interfaces of the base stations 1 to 3 with the mobile switching centers 4 and 5, the mobile switching centers 4 and 5 and
15 the PSTN 6 have communication capabilities in an ATM (Asynchronous Transfer Mode) as well as in an ordinary communication mode, and they will be described to carry out ATM communications.

 Moreover, the subscriber stations MS11 to MS14 and the WS21 to WS23 and the base stations exchange signals through the use of a digital
20 modulation system; let it be assumed that they are radio-linked, for example, by an FDMA/TDD (Time Division Duplex) system which is a frequency division multiple access/time division two-way communication system, CDMA/TDD (Code division Multiple Access/Time Division Duplex) system which is a code division multiple access/time division two-way
25 communication system, TDMA/FDD (Multi-carriers Time division Multiple Access/Frequency Division Duplex) system which is a code division multi-carrier time division/frequency division two-way communication

system, TDMA/TDD system, time division CDMA/FDD system, or time division CDMA/TDD system.

Fig. 2 is an explanatory diagram depicting examples of time slots for TDMA and time division CDMA PCS (Personal Communication System) and
 5 for a cellular system. In Fig. 2, #31-0A to 3A are time division CDMA time slots for a PCS high-speed data transmission downlink in a first frame, and #31-0B to 3B are time division CDMA time slots for in the first frame.

#32-0A to #32-3B are time division CDMA time slots for PCS low-speed data transmission in the first frame; #33-1A to #33-2B and #35-1A
 10 to #35-2B are TDMA time slots for PCS low-speed data transmission in the first frame; and #34-0A to #34-3B are TDMA time slots for PCS medium-speed data transmission in the first frame.

#36-1A to #35-2B are TDMA time slots for PCS high-speed data transmission in the first frame; #35-0A to #35-3B are TDMA time slots for
 15 cellular low-speed data transmission in the first frame; and #37-0A to #37-3B are time division CDMA time slots for cellular high-speed data transmission in the first and second frames.

Incidentally, Fig. 2 shows Up-Link and Down-Link of the TDD (Time Division Duplex) system, the Up-Link being time slots expressed by $R1_{0B}$ to
 20 $R1_{3B}$ on the time axis and the Down-Link time slots expressed by $T1_{0A}$ to $T1_{3A}$ and $T2_{0A}$ to $T2_{3A}$ on the time axis. The time slots $R1_{0B}$ to $R1_{3B}$ of UP-Link and the time slots $T1_{0A}$ to $T1_{3A}$ of Down-Link constitute one frame, and time slots $T2_{0A}$ to $T2_{3A}$ are those belonging to the next frame. That is, Fig. 2 expresses one and a half frame.

25 Fig. 3 is an explanatory diagram showing other examples of TDMA and time division CDMA time slots for PCS and cellular system use; the time slots of the same names as those in Fig. 2 are identical with those in the latter,

and hence no description will be repeated.

#31-4A to #31-5A are asymmetrical portions of Down-Link in time division CDMA time slots for PCS high-speed data transmission in the first frame, which are time slots to be used when the amount of information to be sent from the base station to the subscriber station is larger than the amount of information to be sent from the subscriber station to the base station.

#31-0B to #31-1B are time slots of UP-Link in the first frame. That is, all time slots contained in those T10A to T15A are time slots in the first and other frames which belong to Down-Link. Similarly, all time slots contained in R10B to R11B are time slots in the first and other frames which belong to Up-Link.

Fig. 3 shows the case of an asymmetrical TDD system in which the transmission timing of Up-Link and the transmission timing of Down-Link differ in the TDD frame time length. The present invention is applied not only to such a symmetrical timing TDD system as depicted in Fig. 2 but also to such an asymmetrical TDD system as depicted in Fig. 3; that is, the invention is also applied to the case where the uplink and the downlink of the communication line interconnecting the base station and the subscriber station differ in the amount of data to be sent.

Fig. 4 is an explanatory diagram showing, by way of example, transmission rates of the up- and the down-links for radio communication between subscriber stations and the base station; it is shown that usable transmission rates differ with the kind of multimedia that each subscriber station utilizes.

The transmission rate identified as "intermittent" in Fig. 4 is a transmission rate below 1 kbps, and the "intermittent" transmission rate is used once for multi-frame in the mobile communication system; while the

subscriber station is in the course of processing information of its own, no communications are needed between the base station and the subscriber station during this period, but this transmission rate is a low-speed one which is used when the communication line is not off.

5 Fig. 5 is an explanatory diagram showing a list of channels provisionally pre-assigned time slots for transmission of the next frame and channels which are actually used.

For example, in the case of subscriber station No. 19980428 (MS11), seven kinds of transmission rates from 1 kbps to 24 kbps, including
10 "intermittent," can be set in the uplink (see Fig. 4), but in Fig. 5 four kinds of channels (first to fourth channels) are set as usable channels. That is, Fig. 5 defines the kinds of transmission rates that can be changed during communication.

This setting defines the kinds of communication channels that can be
15 dynamically assigned.

Incidentally, Fig. 5 shows that the time slot #31-0B is currently set in the Up-Link for subscriber stations Nos. 19980601 (WS21) and 19980614 (WS23) to send data therefrom to the base station at the transmission rate 1024 kbps; since this radio wave is TD-CDMA, the same time slot is shared
20 by a plurality of signals in this case. Naturally, spreading codes of the plural radio waves sharing the same time slot are chosen so that they cross at right angles, but in Fig. 5 no information about these codes is shown.

Furthermore, Down-Link of a subscriber station No. 19980428 (MS11) is shown to currently use the fourth channel (the time slot #32-1A
25 with a transmission rate 2048 kbps); for example, when it becomes necessary to switch Down-Link to the second channel (the time slot #32-1A with a transmission rate 2 kbps) to send a small amount of information after

completion of sending the large amount of information, the channel is immediately switched at that point in time.

Fig. 6 is a state transition diagram showing channel switching. The state transition diagram shows the state of the downlink or uplink between one subscriber station and one base station. When plural subscriber stations are radio-connected to the base station, the number of state transition diagrams is a multiple of the number of subscriber stations connected. In addition, since the line state differs with each subscriber station, it is needless to say the mobile switching centers 4 and 5 control the base station, taking into consideration the current state of the subscriber stations radio-connected to the base station.

Fig. 7 is a block diagram illustrating the inside (change request means) of the base station of the mobile communication system according to Embodiment 1 of the present invention. Reference numeral 61 denotes a network interface which receives from a mobile switching center 4 ATM information coming from PSTN 6; 62 denotes a FIFO (Fast-in-Fast-out) memory which stores the ATM information received by the network interface 61; 63 denotes a memory measuring instrument which measures the amount of ATM information currently remaining in the FIFO memory 62 (an instantaneous amount of data which has yet to be sent to the subscriber station); and 64 denotes a clock generator which generates a clock.

Reference numeral 65 denotes a time slot processor which performs a selection process of selecting a time slot to be used for the transmission of the next frame in accordance with the amount of ATM information remaining in the memory measured by the memory measuring instrument 63; 66 denotes a real channel memory which stores a channel currently in use; 67 denotes a provisional channel memory provisionally pre-assigned a time slot to be used

for the transmission of the next frame; 68 denotes a frame generator which, under instructions from the time slot processor 65, extracts from the FIFO memory 62 the ATM information to be sent to the subscriber station, adds the ATM information with TS change information (change information about he
 5 time slot to be used for the transmission of the next frame) and check information, and generates a frame which is sent to the subscriber station; 69 denotes a local oscillator which generates a carrier under instructions from the time slot processor 65; and 70 denotes a modulator by which the frame generated by the frame generator 68 is modulated to the carrier generated by
 10 the local oscillator 69.

Reference numeral 71 denotes an amplifier for amplifying the carrier which is output from the modulator 70; 72 denotes a diplexer; 73 denotes an antenna; and 74 denotes a receiving part.

Next, the operation of Embodiment 1 will be described below.

15 This embodiment will be described in connection with the case of changing the transmission rate when the base station 1 is sending the ATM information to the subscriber station MS11.

In the first place, upon receiving from the mobile switching center 4 (see Fig. 16) the ATM information coming from the PSTN 6, the network
 20 interface 61 stores the ATM information in the FIFO memory 62.

In this case, the transmission rate of the ATM information that the network interface 61 is not constant owing to the characteristic of the ATM transmission system. For example, if the transmission rate of the ATM information is made constant which is sent after being read out of the FIFO
 25 memory 62, the amount of ATM information remaining in the FIFO memory 62 varies.

In view of the above, the memory measuring instrument 63 measures

the amount of ATM information currently remaining in the FIFO memory 62 and outputs the measured amount of information remaining in the memory to the time slot processor 65.

When the amount of ATM information remaining differs from that in the previous frame transmission, the time slot processor 65 outputs a TS change information adding instruction to the frame generator 68 to suppress a change in the amount of information remaining in the FIFO memory 62.

More specifically, letting Z represent the amount of information remaining in the FIFO memory 62, the time slot processor retrieves the following four inequalities for an inequality for which an inequality sign holds, and selects, as the time slot for the next frame transmission over the downlink of the subscriber station, the time slot set in the channel corresponding to the inequality for which an inequality sign holds (see Fig. 5). It is assumed here that the time length of one frame is 10 ms.

- (1) $20.48 \text{ kb} \leq Z$
→ 4th channel (time slot #31-1A of 2048 kbps)
- (2) $320 \text{ b} \leq Z < 20.48 \text{ kb}$
→ 3rd channel (time slot #37-0A of 32 kbps)
- (3) $20 \text{ b} \leq Z < 320 \text{ b}$
→ 2nd channel (time slot #32-1A of 2 kbps)
- (4) $Z < 20 \text{ b}$
→ 1st channel (time slot #35-0A of intermittent transmission rate)

Accordingly, when the amount of information remaining in the FIFO memory 62 exceeds, for instance, 20.48 kb (= 2048 kbps × 10 ms), the time slot #31-1A of the transmission rate 2048 kbps set in the fourth channel is selected for the next frame transmission.

When the time slot processor 65 selects the time slot for the next

frame transmission as described above, it supplies the frame generator 68 with an instruction for adding TS change information indicating the selected time slot and a frame generating instruction (no frame generating instruction being needed when the TS change information adding instruction is used also as the

5 frame generating instruction).

Sub
AI

In the case where the amount of ATM information remaining in the memory 62 is not different from that at the time of the previous frame transmission, however, there is no need to change the transmission rate for the next frame. Hence, the time slot processor outputs only the frame generating

10 instruction to the frame generator 68 without outputting thereto the TS change information adding instruction.

And, upon receiving the TS change information adding instruction and the frame generating instruction from the time slot processor 65, the frame generator 68 adds, as depicted in Fig. 8, TS change information and check

15 information (for example, CRC code) to the ATM information read out of the FIFO memory 62 (The amount of ATM information read out of the memory is determined under instructions from the time slot processor 65 but corresponds to the transmission rate of the time slot determined at the time of the previous frame transmission. For example, when the time slot #31-1A of the

20 transmission rate 2048 kbps was selected at the time of previous transmission, ATM information of 20.48 kbps is read out of the FIFO memory 62), thereby forming the frame that is sent to the subscriber station MS11.

Incidentally, when receiving only the frame generating instructions, the frame generator adds the check information to the ATM information to

25 form the frame.

On the other hand, the local oscillator 69 generates a carrier under instructions from the time slot processor 65. That is, the oscillator generates

a carrier which corresponds to the transmission rate of the time slot determined at the time of sending the previous frame.

And, when the frame generator 68 provides the frame to be sent this time, the modulator 70 modulates the frame to the carrier generated by the local oscillator 69, and provides the modulated output to the amplifier 71, whose output is sent by radio waves from the antenna 73.

When the radio waves are radiated from the antenna 73 in this way, the subscriber station MS11 receives the radio waves.

And, upon reading out from the radio waves the TS change information forming the frame, time slot change means of the subscriber station MS 11 changes the transmission rate for reception of the next frame, that is, the time slot for reception of the next frame in accordance with the TS change information.

As is evident from the above, since Embodiment 1 has a configuration in which upon receiving the TS change information from the base station 1, the subscriber station MS11 changes the time slot for reception of the frame from the base station 1 in accordance with the TS change information, the base station 1 can use the new time slot to send the next and subsequent frames without having to receive acceptance/rejection information which would otherwise be sent from the subscriber station in reply to the TS change information. Accordingly, even when the amount of ATM information to be sent varies greatly, it is possible to ensure the immediacy of ATM information sent in real time.

25 EMBODIMENT 2

A description will be given of a second embodiment (Embodiment 2) of the present invention.

In Embodiment 1 described above, at the time of selecting the time slot for the transmission of the next frame in accordance with the amount of ATM information remaining, the time slot processor 65 retrieves an inequality for which an inequality sign holds, and selects the time slot set in the channel corresponding to the inequality. However, it is also possible to employ a configuration in which a time slot is provisionally pre-assigned to each channel as depicted in Fig. 9 and, when it becomes necessary to change the transmission rate, the channel is used which has been pre-assigned the time slot of the required transmission rate.

That is, when the transmission rate needs to be change, the time slot processor 65 determines the transmission rate for the next frame based on the amount of ATM information remaining. Concretely, if the time length of one frame is 10 ms, the time slot processor multiplies the amount of ATM information remaining by 100 to provisionally determine the transmission rate for the next frame.

For example, when the amount of ATM information remaining is 350 b, the transmission rate for the next frame is provisionally determined to be 35 Kbps.

When having thus provisionally determined the transmission rate for the next frame, the time slot processor 65 refers to the provisional channel memory 67 in which a time slot has been provisionally assigned, and selects the channel corresponding to the provisionally determined transmission rate. For instance, when the transmission rate of the downlink for transmission to the subscriber station MS11 is provisionally determined to be 35 Kbps, the third channel (time slot #37-0A of 32 kbps) is selected.

Upon selection of the channel corresponding to the provisionally determined transmission rate, the time slot processor 65 transfers the channel

information to the actual channel memory 66 to perform a process for changing the transmission rate for the next frame and, at the same time, adds the TS change information to the ATM information for transmission to the subscriber station MS11 as in Embodiment 1.

5 Incidentally, a certain amount of time is needed to update the stored contents of the actual channel memory 66 after a request change of the transmission rate is made. Hence, when the same time slot has been assigned to plural channels (in the case of Fig. 9, the same time slot has been assigned to the third channel of the downlink of the subscriber station MS11 and the third channel of the downlink of the subscriber station MS12), if requests for change of the transmission rate in plural radio channels are made at about the same time, there is a case where the transmission rate in one of the plural radio channels cannot be changed.

10 For example, if the downlink of the subscriber station MS11 is changed to the third channel (time slot #37-0A of 32 kbps), the downlink of the subscriber station MS12 cannot be changed to the third channel (time slot #37-0A of 32 kbps). Accordingly, as depicted in Fig. 10, that one of currently unused time slots which has a time slot equal to that of the time slot #37-0A (for example, time slot #37-3A) is assigned to the third channel
15 concerned.

20 In this way, the downlink of the subscriber station MS12 is switched to the third channel (time slot #37-3A of 32 kbps).

 Incidentally, according to Embodiment 2, since usable channels have been pre-assigned at the time of changing the time slot, the channel switching
25 can be done at once.

EMBODIMENT 3

A description will be given of a third embodiment (Embodiment 3) of the present invention.

In Embodiment 1 described above, upon receiving the TS change information from the time slot processor 65 sends the TS change information, the subscriber station immediately changes the time slot. However, it is also possible to employ a configuration in which the time slot processor sends to the subscriber station reservation information indicating the timing for changing the time slot and the subscriber station determines the time slot change timing in accordance with the reservation information.

That is, at the time of adding the TS change information to the ATM information, the time slot processor 65 adds the ATM information with the reservation information indicating the timing for changing the time slot (for example, when "-5" is added as the reservation information, the time slot is changed after five frames) as shown in Fig. 11.

Upon receiving the ATM information added with the TS change information and the reservation information, the subscriber station changes the time slot in accordance with the TS change information as in Embodiment 1 described above, but it does not necessarily change the time slot immediately after receiving the TS change information but instead determines the timing for changing the time slot in accordance with the reservation information.

For example, when "-5" is added as the reservation information, the subscriber station uses the new time slot after the lapse of five frame periods.

Incidentally, it is also possible to employ a configuration in which the subscriber station count reservation information up by one ("-5" → "-4" → "-3" → "-2" → "-1" → "0") upon each sending of the ATM information from the time slot processor 65 and changes the time slot when the reservation

information reaches "0." Alternatively, the time slot processor 65 sends the reservation information once and the subscriber station counts the number of times it receives frames after the reception of the reservation information, thereby obtaining the timing for changing the time slot.

5 As will be seen from the above, according to Embodiment 3, since the TS change information is sent to the subscriber station together with the reservation information indicating the timing for changing the time slot, the time slot changing process can be prepared in anticipation of a variation in the amount of data to be sent. Accordingly, the time slot can be changed in
10 good time, making it possible to judge the state of congestion in the frequency band used. Moreover, since time slots with no ATM information can also be reserved in the previous frame (it can also be set that, for example, reservation information "2" means that no information will be contained in the time slots for the subsequent two frames), equivalent noise can be reduced when the
15 time division CDMA system is adopted.

EMBODIMENT 4

A description will be given of a fourth embodiment (Embodiment 4) of the present invention.

20 In Embodiment 3 described above, the subscriber station determines the time slot change timing based on the reservation information sent thereto, but since in this instance the time slot is actually changed several frames after the sending of the TS change information, another subscriber station may sometimes use the time slot concerned, making it impossible to use the
25 desired time slot.

To avoid this, according to Embodiment 4, when the desired time slot becomes unusable before the time slot changing means of the subscriber

station changes the time slot, the time slot processor 65 sends TS correcting information designating another time slot to the subscriber station as shown in Fig. 12.

5 In this way, the time slot changing means of the subscriber station changes the time slot based on the TS correcting information; accordingly, even if the desired time slot becomes unusable, it is possible to secure the required transmission rate.

EMBODIMENT 5

10 A description will be given of a fifth embodiment (Embodiment 5) of the present invention.

In Embodiment 4 described above, the subscriber station determines the time slot change timing based on the reservation information sent thereto, it is also possible to reserve a change of the time slot provisionally assigned to
15 each channel.

That is, when the time slot processor 65 sends reservation information to the subscriber station, the time slot is changed after several frames and the stored contents of the provisional channel memory 67 are reflected on the actual channel memory 66. However, to cope with variations in the amount
20 of data to be sent after several frames, it is also possible to accept a reservation that updates the stored contents of the provisional channel memory 67.

For example, a reservation is made which provisionally assigns #32-2A to the downlink of the second channel of the subscriber station MS11
25 after several frames.

Accordingly, it is possible to prepare changing the time slot provisionally assigned to each channel.

EMBODIMENT 6

A description will be given of a sixth embodiment (Embodiment 6) of the present invention.

In Embodiments 1 through 5 described above, upon receiving the TS change information sent from the time slot processor, the subscriber station changes the time slot based on the TS change information, but unconditional change of the time slot entails the risk of cutting the radio connection.

To avoid this, according to Embodiment 6, the change of the time slot is allowed as long as the state of current radio communication meets predetermined conditions.

Concretely, as depicted in Fig. 13, when a request for a change of the channel capacity is made (step ST1), the time slot processor 65 judges whether the new channel capacity is larger than the channel capacity currently used for communication (step ST2).

When the new channel capacity is larger than the channel capacity currently used for communication, an amount of increase in the sending power caused by an increase in the channel capacity is computed from the current transmission rate DR1 and the new transmission rate DR2 (step ST3).

$$C \text{ (dB)} = 10 \times \log (DR2/DR1)$$

Upon counting the amount of increase C in the sending power, the time slot processor 65 judges whether the transmitter of the base station can increase the current sending power by C (dB) (step ST4).

When the transmitter of the base station can increase the current sending power by C (dB), an increase in the channel capacity will be unlikely to cause cutting the radio connection. Accordingly, the time slot processor 65 permits the change of the channel capacity (step ST5) and sends the TS change information to the subscriber station in the same manner as described

above with reference to Embodiments 1 to 5.

On the other hand, when the transmitter of the base station cannot increase the current sending power by C (dB), an increase in the channel capacity will be likely to cause cutting the radio connection, and hence the time slot processor does not permit the change of the channel capacity (step ST6) and stops sending the TS change information. In the case where the sending power of the transmitter of the base station can be increased to some extent, it is possible to set the channel capacity corresponding to the amount of increase and send the TS change information accordingly.

When the new channel capacity is smaller than the current channel capacity, the time slot processor 65 compares the sensitivity of the receiver of the subscriber station and its minimum sensitivity and judges whether the sensitivity of the receiver of the subscriber station is higher than the minimum sensitivity in excess of A dB (sep ST7).

That is, when the sensitivity of the receiver of the subscriber station is higher than the minimum sensitivity in excess A dB, a change of the time slot will be unlikely to cause cutting the radio connection, and hence the time slot processor permits a change of the channel capacity and sends the TS change information to the subscriber station.

On the other hand, when the sensitivity of the receiver of the subscriber station is so low as to be much the same as the minimum sensitivity and is not higher than the latter in excess of A dB, a change of the time slot will be likely to cause cutting the radio connection, and hence the time slot processor judges whether the current sending power of the transmitter of the base station can be increase by A (dB) (step ST8).

That is, even if the sensitivity of the receiver is low, an increase in the sending power of the transmitter reduces the possibility of the radio

connecting being cut even if the time slot is changed; hence, the time slot processor judges whether the current sending power of the transmitter of the base station can be increased by A (dB).

When the current sending power of the transmitter of the base station
5 can be increased by A (dB), the time slot processor permits a change of the channel capacity and sends the TS change information to the subscriber station.

When the current sending power of the transmitter of the base station
cannot be increased by A (dB), the time slot processor does not permit a
10 change of the channel capacity (step ST6) and stops sending the TS change information.

As will be seen from the above, according to Embodiment 6, when the
channel capacity increases, it is determined whether to permit or inhibit the
change of the transmission by referring to the sendable power of the
transmitter in the base station, and when the channel capacity decreases, it is
15 determined whether to permit or inhibit the change of the transmission rate by
referring to the sensitivity of the receiver in the subscriber station and the
sendable power of the transmitter in the base station. Hence, this
embodiment prevents the radio connection from being cut by a change of the
20 time slot.

EMBODIMENT 7

Fig. 14 is a block diagram illustrating the inside (change request
means) of the subscriber station in the mobile communication system
25 according to a seventh embodiment (Embodiment 7) of the present invention.
Reference numeral 81 denotes a man-machine interface such as a keyboard,
image display part, voice input/output part or the like; 82 denotes a FIFO

memory for storing data input from the man-machine interface 81; 83 denotes a memory measuring instrument for measuring the amount of information currently remaining in the FIFO memory 82 (the instantaneous amount of data which has yet to be sent to the subscriber station); and 84 denotes a clock generator for generating a clock.

Reference numeral 85 denotes a time slot processor which performs a selection process of selecting a time slot to be used for the transmission of the next frame in accordance with the amount of data remaining in the memory measured by the memory measuring instrument 83; 86 denotes an actual channel memory which stores a channel currently in use; 87 denotes a provisional channel memory provisionally pre-assigned a time slot to be used for the transmission of the next frame; 88 denotes a frame generator which, under instructions from the time slot processor 85, extracts from the FIFO memory 82 the data to be sent to the subscriber station, and adds the data with TS change information and check information to form a frame which is sent to the subscriber station; 89 denotes a local oscillator which generates a carrier under instructions from the time slot processor 85; and 90 denotes a modulator by which the frame generated by the frame generator 88 is modulated to the carrier generated by the local oscillator 89.

Reference numeral 91 denotes an amplifier for amplifying the carrier which is output from the modulator 90; 92 denotes a diplexer; 93 denotes an antenna; and 94 denotes a receiving part.

Next, the operation of this embodiment will be described below.

While in Embodiments 1 to 6 the base station instructs the subscriber station to change the time slot, the subscriber station may also be designed to change the time slot independently by incorporating in the subscriber station the same change request means as that of the base station depicted in Fig. 7.

That is, the time slot processor 85 of the subscriber station determines the time slot for the transmission of the next frame (or for the transmission after several frames) in accordance with the amount of data remaining in the memory measured by the memory measuring instrument 83, and sends to the
 5 base station a frame in which TS change information and reservation information are added to transmission data.

Since this embodiment is identical with Embodiments 1 to 6 except that the subscriber station determines the transmission rate in place of the base station, no detailed description will be given of this embodiment.

10 Incidentally, Fig. 15 is a block diagram illustrating time slot changing means of the base station which receives the TS change information from the subscriber station and changes the time slot (the time slot changing means of the subscriber station being also substantially identical in construction therewith). Reference numeral 101 denotes a receiving part for receiving the
 15 frame added with the TS change information; 102 denotes a receiving local oscillator; 103 denotes a demodulator for demodulating the frame received by the receiving part 101; and 104 denotes a frame decoding/data detector which decodes the frame demodulated by the demodulator 103 and, when detecting the TS change information, outputs the TS change information to the time slot
 20 processor 65.

Upon receiving the TS change information from the frame decoding/data detector 104, the time slot processor 65 changes the time slot for reception of the next frame in accordance with the TS change information.

25 EFFECT OF THE INVENTION

As described above, the mobile communication system according to the present invention has a communication channel in which uplink and

downlink channel capacities differ from each other, and is suitable for use with such transmission systems as a time division multiple access (TDMA) system, a code division multiple access/time division duplex (CDMA/TDD) system, and a time division CDMA (Time Divided CDMA) system.

5

It will be apparent that many modifications and variations may be effected without departing from the scope of the novel concepts of the present invention.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185
2186
2187
2188
2189
2190
2191
2192
2193
2194
2195
2196
2197
2198
2199
2200
2201
2202
2203
2204
2205
2206
2207
2208
2209